Assignment 3

March 17, 2022

[97]:

```
from sklearn.model_selection import train_test_split
from sklearn.datasets import fetch_lfw_people
import matplotlib.pyplot as plt
import matplotlib.cm as cm
import numpy as np
import pandas as pd
import math
from sklearn.neighbors import KNeighborsClassifier
import warnings
warnings.filterwarnings('ignore')
```

[98]:

```
def standardize_sr(sr, avg, std):
    sr_standardized = sr.apply(lambda x: ((x - avg) / std))
    return sr_standardized
```

[99]:

```
def standardize_train_data(df):
    df_copy = df.copy()
    df_std = df_copy.apply(lambda x: standardize_sr(x, x.mean(), x.std()))
    return pd.DataFrame(df_std)
```

[100]:

```
def standardize_test_data(df, df_train):
    df_copy = df.copy()
    df_std = df_copy.apply(lambda x: standardize_sr(x, df_train[x.name].mean(),␣
 ↪df_train[x.name].std()))
    return pd.DataFrame(df_std)
```

[101]:

```
def dist_between_rows(sr_train, sr_test):
    return np.linalg.norm(sr_test - sr_train)
```

[102]:

```
def knn_classifier(train_data, train_target, test_data, test_target):
    positive_count = 0
    negative_count = 0
    test_data_len = len(df_test_data)
    for test_index, test_row in test_data.iterrows():
        minimum_distance = math.inf
        wanted_row_index = 0
        for train_index, train_row in train_data.iterrows():
            distance = dist_between_rows(test_row, train_row)
            if distance < minimum_distance:
                minimum_distance = distance
                wanted_row_index = train_index
        if train_target.loc[wanted_row_index][0] == test_target.
 ↪loc[test_index][0]:
            positive_count += 1
        else:
            negative_count += 1
    score = (positive_count / (positive_count + negative_count))
    return score
```

[103]:
```
def encode(e_val):
    k = 1
    eigen_sum = e_val.sum()
    while (np.sum(e_val[0:k]) / eigen_sum) < 0.95:
        k += 1
    return k
```

[104]:
```
def covariance(df):
    df_covar_mat = pd.DataFrame(np.dot(df.T, df))
    df_covar_mat /= len(df) - 1
    return np.linalg.eig(df_covar_mat)
```

[105]:
```
def whiten(data):
    u, _, v = np.linalg.svd(data, full_matrices = False)
    return np.dot(u, v)
```

[106]:
```
def pca(data, e_val, e_vec, dimension):
    e_val = e_val.copy()
    e_vec = e_vec.copy()
    indices_l = []
    vectors_l = []
    for i in range(dimension):
        index = e_val.idxmax(axis = 0)[0]
        indices_l.append(index)
        e_val.loc[index] = -math.inf
    for x in indices_l:
        vectors_l.append(e_vec[x].to_numpy())
    df = pd.DataFrame(vectors_l).T
    return np.dot(data, np.transpose(vectors_l))
```

0.1 All the code given to us

[107]:
```
people = fetch_lfw_people(min_faces_per_person=20, resize=.7)
image_shape = people.images[0].shape
fig, axes = plt.subplots(2, 5, figsize=(15,8),
                         subplot_kw={'xticks': (), 'yticks': ()})
```

```
for target, image, ax in zip(people.target, people.images, axes.ravel()):
    ax.imshow(image, cmap=cm.gray)
    ax.set_title(people.target_names[target])
mask = np.zeros(people.target.shape, dtype=bool)
for target in np.unique(people.target):
    mask[np.where(people.target == target)[0][:50]] = 1
x_people = people.data[mask]
y_people = people.target[mask]
x_people = x_people / 255
x_train, x_test, y_train, y_test = train_test_split(x_people, y_people,␣
 ↪stratify = y_people, random_state=0)
knn = KNeighborsClassifier(n_neighbors=1)
knn.fit(x_train, y_train)
print("Test set score of 1-nn: {:.2f}".format(knn.score(x_test, y_test)))
```

```
Test set score of 1-nn: 0.46
```

0.2 My KNN Solution

[108]:

```
df_train_data = pd.DataFrame(x_train)
df_test_data = pd.DataFrame(x_test)
df_train_target = pd.DataFrame(y_train)
df_test_target = pd.DataFrame(y_test)
```

[109]:

```
knn_score = knn_classifier(df_train_data, df_train_target, df_test_data,␣
 ↪df_test_target)
```

```
[110]: knn_score
```

```
[110]: 0.463768115942029
```

0.3 100 Dimension PCA

```
[111]: df_data = pd.DataFrame(x_people)
```

```
[112]: df_data_std = standardize_train_data(df_data)
```

```
[113]: eig_val, eig_vec = covariance(df_data_std)
```

```
[114]: df_eig_val = pd.DataFrame(eig_val)
       df_eig_vec = pd.DataFrame(eig_vec)
```

```
[115]: hundred_dim_mat = pca(df_data_std, df_eig_val, df_eig_vec, 100)
```

```
[116]: df_hundred_dim_data = pd.DataFrame(hundred_dim_mat)
```

```
[117]: hundred_dim_x_train, hundred_dim_x_test, hundred_dim_y_train,␣
         ↪hundred_dim_y_test = train_test_split(hundred_dim_mat, y_people, stratify =␣
         ↪y_people, random_state=0)
```

```
[118]: df_hundred_dim_train_data = pd.DataFrame(hundred_dim_x_train)
       df_hundred_dim_test_data = pd.DataFrame(hundred_dim_x_test)
       df_hundred_dim_train_target = pd.DataFrame(hundred_dim_y_train)
       df_hundred_dim_test_target = pd.DataFrame(hundred_dim_y_test)
```

```
[119]: hundred_dim_knn_score = knn_classifier(df_hundred_dim_train_data,␣
         ↪df_hundred_dim_train_target, df_hundred_dim_test_data,␣
         ↪df_hundred_dim_test_target)
```

```
[120]: hundred_dim_knn_score
```

```
[120]: 0.45652173913043476
```

0.4 100 Dimension Whitened Data

```
[121]: hundred_dim_whitened_train_data = whiten(df_hundred_dim_train_data)
       hundred_dim_whitened_test_data = whiten(df_hundred_dim_test_data)
```

```
[122]: _, _, hundred_dim_whitened_train_target, hundred_dim_whitened_test_target =␣
         ↪train_test_split(hundred_dim_mat, y_people, stratify = y_people,␣
         ↪random_state=0)
```

```
[123]: df_hundred_dim_whitened_train_data = pd.
         ↪DataFrame(hundred_dim_whitened_train_data)
       df_hundred_dim_whitened_test_data = pd.DataFrame(hundred_dim_whitened_test_data)
```

```
df_hundred_dim_whitened_train_target = pd.
  ↪DataFrame(hundred_dim_whitened_train_target)
df_hundred_dim_whitened_test_target = pd.
  ↪DataFrame(hundred_dim_whitened_test_target)
```

[124]:
```
hundred_dim_whitened_score = knn_classifier(df_hundred_dim_whitened_train_data,␣
  ↪df_hundred_dim_whitened_train_target, df_hundred_dim_whitened_test_data,␣
  ↪df_hundred_dim_whitened_test_target)
```

[125]:
```
hundred_dim_whitened_score
```

[125]:
```
0.5579710144927537
```

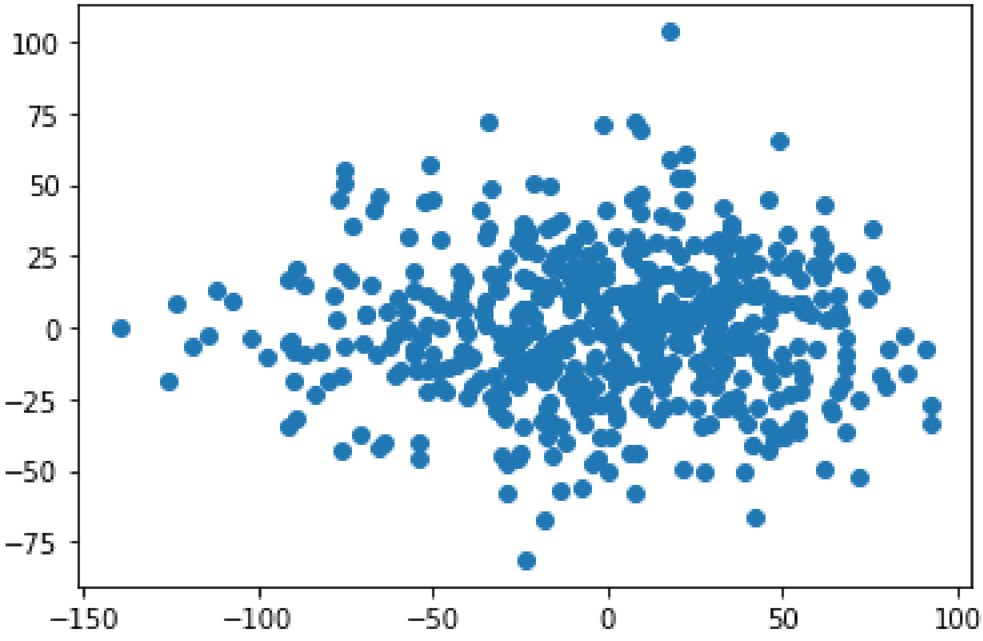
0.5 2 Dimension

[126]:
```
two_dim_eig_val, two_dim_eig_vec = covariance(df_data_std)
```

[127]:
```
two_dim_data = pca(df_data_std, pd.DataFrame(two_dim_eig_val), pd.
  ↪DataFrame(two_dim_eig_vec), 2)
```

[128]:
```
df_two_dim_data = pd.DataFrame(two_dim_data)
```

[129]:
```
plt.scatter(df_two_dim_data[0], df_two_dim_data[1])
plt.show()
```



1 Eigenfaces

[130]:
```
PC1 = df_eig_vec.astype(np.float64)[0]
PC2 = df_eig_vec.astype(np.float64)[1]
```

[131]:
```
stdev = pd.DataFrame(x_people).std().to_numpy()
average = pd.DataFrame(x_people).mean().to_numpy()
```

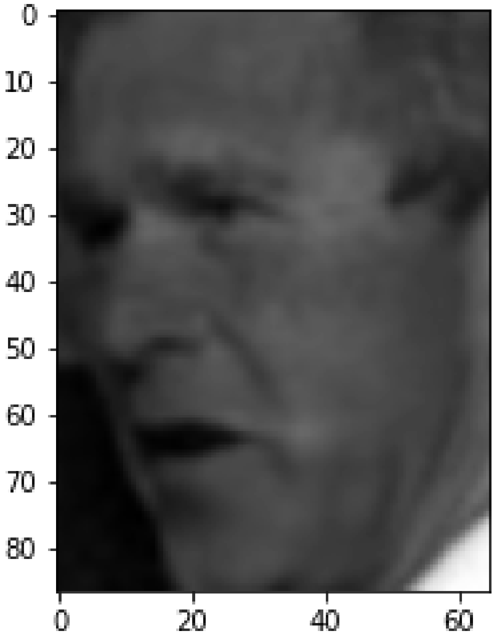
1.1 PC1 Min Max

[132]:
```
PC1_dot_prod = np.dot(x_test, PC1)
sr_PC1_dot_prod = pd.Series(PC1_dot_prod)

PC1_max_index = sr_PC1_dot_prod.idxmax()
PC1_max_val_pic = y_test[PC1_max_index]

PC1_min_index = sr_PC1_dot_prod.idxmin()
PC1_min_val_pic = df_test_target.loc[PC1_min_index].to_numpy()
```

1.1.1 PC1 - Maximum Value

[133]:
```
PC1_max = np.dot(df_test_data.loc[PC1_max_val_pic].to_numpy(), np.
 ↪dot(PC1_dot_prod, PC1_dot_prod.transpose()))
PC1_max_res = (PC1_max * stdev) + average
plt.gray()
plt.imshow(PC1_max_res.reshape(87, 65))
```

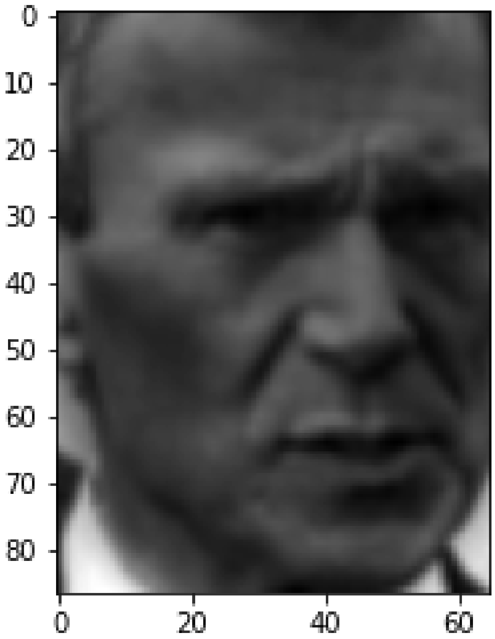
[133]:
```
<matplotlib.image.AxesImage at 0x22f98c19f70>
```



1.1.2 PC1 - Minimum Value

[134]:
```
PC1_min = np.dot(df_test_data.loc[PC1_min_val_pic].to_numpy(), np.
 ↪dot(PC1_dot_prod, PC1_dot_prod.transpose()))
PC1_min_res = (PC1_min * stdev) + average
plt.imshow(PC1_min_res.reshape(87, 65))
```

[134]:
```
<matplotlib.image.AxesImage at 0x22f98bd0c40>
```



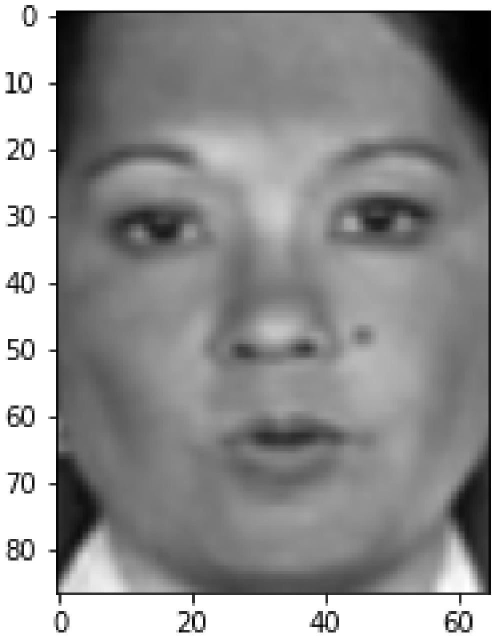
1.2 PC2 Min Max

[145]:
```
PC2_dot_prod = np.dot(x_test, PC2)
sr_PC2_dot_prod = pd.Series(PC2_dot_prod)

PC2_max_index = sr_PC2_dot_prod.idxmax()
PC2_max_val_pic = df_test_target.loc[PC2_max_index].to_numpy()

PC2_min_index = sr_PC2_dot_prod.idxmin()
PC2_min_val_pic = df_test_target.loc[PC2_min_index].to_numpy()
```

1.2.1 PC2 Maximum Value

```
[146]: PC2_max = np.dot(df_test_data.loc[PC2_max_val_pic].to_numpy(), np.
         ↪dot(PC2_dot_prod, PC2_dot_prod.transpose()))
       PC2_max_res = (PC2_max * stdev) + average
       plt.imshow(PC2_max_res.reshape(87, 65))
```

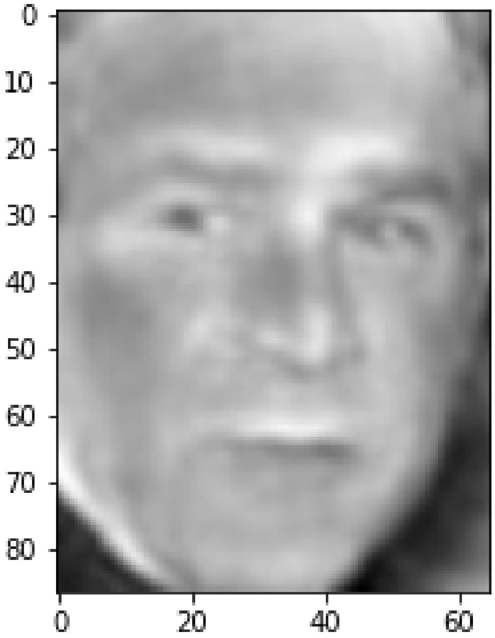
```
[146]: <matplotlib.image.AxesImage at 0x22fa1270bb0>
```



1.2.2 PC2 Minimum Value

```
[147]: PC2_min = np.dot(df_test_data.loc[PC2_min_val_pic].to_numpy(), np.
         ↪dot(PC2_dot_prod, PC2_dot_prod.transpose()))
       PC2_min_res = (PC2_min * stdev) + average
       plt.imshow(PC2_min_res.reshape(87, 65))
```

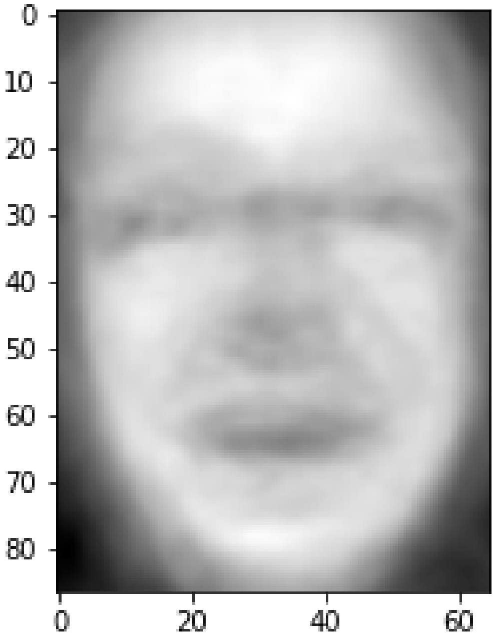
```
[147]: <matplotlib.image.AxesImage at 0x22fa12b4640>
```



1.2.3 Principle Eigenface

```
[148]: plt.imshow(PC1.to_numpy().reshape(87,65))
```

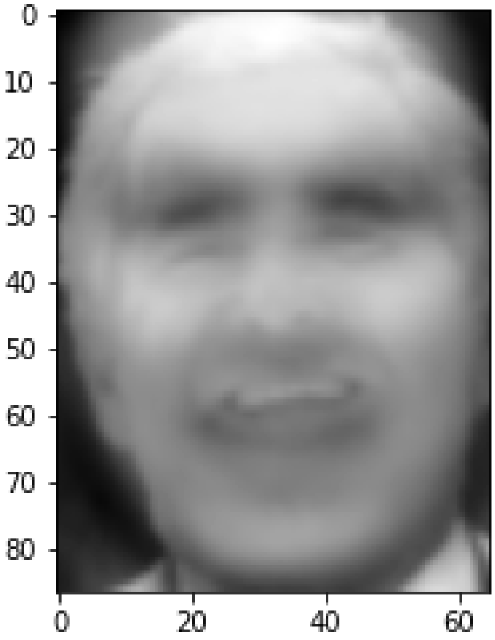
```
[148]: <matplotlib.image.AxesImage at 0x22fa1301dc0>
```



1.2.4 Principle Reconstruction

[149]:
```
principle_reconst = np.dot(df_train_data.loc[0].to_numpy(), np.dot(PC1.
  ↪to_numpy(), PC1.to_numpy().transpose()))
final_res = (principle_reconst * stdev) + average
plt.gray()
plt.imshow(final_res.reshape(87, 65))
```

[149]:
```
<matplotlib.image.AxesImage at 0x22fa13718b0>
```



1.2.5 95% Reconstruction

[150]:
```
res = encode(eig_val.astype(np.float64))
```

[151]:
```
res
```

[151]:
```
134
```

[152]:
```
subsection =  eig_vec.astype(np.float64)[:, :res]
projection = np.dot(df_train_data.loc[0].to_numpy(), np.dot(subsection,␣
  ↪subsection.transpose()))
plt.imshow(projection.reshape(87,65))
```

```
[152]: <matplotlib.image.AxesImage at 0x22fa13e0460>
```